EFFECTS OF PULSE FLOWS ON JUVENILE CHINOOK MIGRATION IN THE STANISLAUS RIVER

2000 ANNUAL REPORT

Prepared for

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EXECUTIVE SUMMARY

In 1993, the San Joaquin and Oakdale irrigation districts initiated investigations examining the timing and abundance of outmigrating juvenile chinook during different flows in the Stanislaus River, a tributary of the San Joaquin River. The study represents a joint effort of the irrigation districts, California Department of Fish and Game and the U.S. Fish and Wildlife Services. It is being conducted by S. P. Cramer and Associates (SPCA) and complements efforts being initiated under the Central Valley Project Improvement Act to double natural production of anadromous fish in central valley streams.

Study efforts concentrate on gaining information needed to understand the effects of water management on juvenile chinook abundance and migration in the river. Investigations have been conducted in most years since 1993 and are refocused annually based on study findings. Target species include fall-run chinook salmon and rainbow trout/steelhead (Table 1). The study addressed three objectives:

- Estimate the number of chinook salmon migrating out of the Stanislaus River.
- Determine the size and smolting characteristics of juvenile chinook and rainbow trout/steelhead migrating from the river.
- Identify factors that influence the timing of juvenile chinook migrating out of the Stanislaus River.

To address these objectives, S.P. Cramer and Associates operates a rotary screw trap in the Stanislaus River near Oakdale, river mile (RM) 40.1, that collects outmigrating juvenile chinook throughout their migration period. Sampling has been conducted at the site in most years since 1993. The biologists also conduct controlled fish releases periodically

to determine trap efficiency. The fish are released at Knights Ferry (RM 54.3) and recaptured near Oakdale, 14.2 miles downstream. Information from the tests is used to expand rotary screw trap recovery rates as needed to estimate the number of chinook salmon migrating from the Stanislaus River.

Besides the Oakdale trap, S.P. Cramer and Associates also operates two traps near Caswell State Park (RM 8.6) under contract with the U.S. Fish and Wildlife Service. Information gained under the study often complements findings under this contract. Relevant information from the study is presented and discussed in this report.

SUMMARY OF FINDINGS

Sampling conducted at the Oakdale site in four years since 1996 indicates that juvenile chinook outmigration follows similar patterns of migration timing and abundance —though these patterns are influenced significantly year to year by climatic changes and other factors. Studies findings to date are discussed below.

Chinook Outmigrant Abundance

Estimated outmigration abundance for 2000 suggests that more than 1.5 million juvenile chinook may migrate down the Stanislaus River past Oakdale in many years. During the 2000 study, an estimated 1,801,098 juvenile chinook outmigrated from the upper Stanislaus River during the season from December 16, 1999 to June 30, 2000. This included an estimated 1,146,201 fry, 591,620 parr and 63,276 smolts. Our estimates suggest that over 1.6 million juveniles migrated down the Stanislaus River past Oakdale in 1999.

Daily catch records for December, which ranged between 25 and 2 fish daily for the first eight days, suggest that sampling for the 2000 study began near the onset of the chinook outmigration period. The daily catch rose in late December and early January with a high catch of 903 chinook on January 10—still eight days before sampling began in 1999. This confirmed our belief that fry emerge throughout the winter and that trapping in 1996, 1998 and 1999 missed much of the fry passage from the winter emergence. Although trapping has begun earlier each year since 1995, the high capture rates from the initiation of sampling indicate that the runs had already started migrating. Sampling for 2000 probably began soon after outmigration started.

Influence Of Flow On Outmigration

The number of juvenile chinook outmigrants often increases following pulse flows, with the effect generally lasting only a few days. In 2000, as in 1996 and 1998, fry outmigration rose significantly after large increases in flows, generally from 340 cfs to more than 700 cfs. For example, in January 2000, outmigration grew from an estimated 860 migrants on January 24 to 182,520 on January 25 after average river flows rose from 447 cfs to 752 cfs. All together, an estimated 324,735 fry outmigrated during two days in this freshet—an event not sampled in previous years. Fry passage peaked again in February, rising from about 9,970 migrants on February 11 to 114,040 migrants on February 14 when flow increased from an average of 359 cfs to 1,544 cfs. As in other study years, the fry outmigration declined a few days later after peak flows dropped and stabilized. Chinook migration did not rise significantly later in the 2000 study when flows increased to over 2,500 cfs, and then to near 4,000 cfs, before dropping and stabilizing near 850 cfs. However, the later flow increases were largely associated with the parr and smolt outmigration. These results suggest that flow increases may have a larger impact on fry migrants than on smolts.

Sustained high flows do not seem to “flush” juvenile chinook out of the river. As in previous years, the large catches seen at Oakdale during pulse flows were not visible at Caswell, 31.5 miles downstream. This suggests that the pulse flows move the juveniles downstream, but do not flush them out of the Stanislaus River.

Rearing Between Oakdale and Caswell

As in 1999, there was a noticalbe difference in the daily mean length of fish captured at Oakdale and Caswell after mid-March 2000. This difference, while not seen in 1996 or 1998, suggests that in some years rearing may take place between the sites.

Influence Of Turbidity On Outmigration

Peaks in fry outmigration during the 2000 study suggest that turbidity levels may influence juvenile chinook movement. For example, the number of captured outmigrants rose from about 1,260 fry/day in mid-January to 182,520 fry/day when turbidity increased from 2 NTU's to 25.6 NTU's on January 25. When flows dropped the following day, turbidity remained high at 11.2 NTU's and a large number of fry continued to migrate. Fry outmigration also peaked in February when flows increased from about 350 cfs to 1,544 cfs and turbidity rose from 2.6 NTU's to 63 NTU's. Several other peaks in outmigration occurred during periods when turbidity increased and flows remained stable.

Others???????

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INTRODUCTION

Historically, the Central Valley drainage of California produced strong runs of chinook salmon (*Oncorhynchus tshawytscha*), with up to 30,000 fall chinook returning to the Stanislaus River. Spawner escapement dropped as commercial fisheries expanded around the turn of the century and annual catches of chinook reaching 4 to 10 million pounds. Other developments in the basin early in the century intensified the run's decline. Stanislaus River chinook were affected by stream blockage and degradation from mining practices, and by the reduction of salmon habitat and streamflows by dams and water diversions (Yoshiyama et al. 1998).

Today, 2,000 to 6,000 chinook salmon return each year to the Stanislaus River. The run is stable, but remains far below its historical abundance. Currently, numerous efforts are underway to improve chinook production in the river system through habitat restoration and flow management. Many of these efforts are being implemented in response to the 1992 Central Valley Project Improvement Act, which directs the U.S. Fish and Wildlife Service to develop and implement a series of restoration programs with the goal of doubling the natural production of anadromous fish in Central Valley streams by the year 2002.

The San Joaquin and Oakdale irrigation districts initiated this study in 1993 to examine the effects of water management on juvenile chinook migration and growth in the Stanislaus River. Sampling of migrating juveniles began in the spring of 1993 with the fishing of a rotary screw trap in the river near Oakdale (RM 40.1). Since then, sampling has been conducted in most years. Target species include fall-run chinook salmon and rainbow trout/steelhead. The study complements efforts being initiated under the Central Valley Project Improvement Act. It is being conducted by S.P. Cramer and Associates (SPCA), and represents a joint effort of the irrigation districts, the California Department of Fish and Game, and the U.S. Fish and

Wildlife Service. Study investigations are providing new information about chinook production and migration in the Stanislaus River, and how these factors may be influenced by changes in flow, temperature, turbidity and other environmental factors. This information is needed to manage the river system more effectively for the benefit of chinook and the public.

SCOPE OF WORK

The 2000 study continued investigations examining the effects of flows on juvenile chinook migration and growth in the Stanislaus River. It addressed three objectives:

- Estimate the number of chinook salmon migrating out of the Stanislaus River.
- Determine the size and smolting characteristics of juvenile chinook and rainbow trout/steelhead migrating out of the river.
- Identify factors that influence the timing of juvenile chinook migrating from the river.

DESCRIPTION OF STUDY AREA

The Stanislaus River begins on the western slopes of the Sierra Nevada's and flows southwest to the confluence with the San Joaquin River on the Central Valley floor (Figure 1). The San Joaquin River flows north, joining the Sacramento River in the Sacramento-San Joaquin Delta. Several dams control flows in the Stanislaus River for flood protection, power generation and water supply. Water uses include irrigation and municipal needs, and recreational activities and water quality control. Goodwin Dam, 58.4 river miles upstream from the San Joaquin River confluence, blocks the upstream migration of adult chinook. Most chinook spawning occurs upstream of the town of Riverbank (RM 34) to Goodwin Dam (RM

58.4).

River miles shown throughout the report were determined with a map wheel and 7.5 minute series USGS quadrangle maps, (Knights Ferry, 1987 and Oakdale, 1987). The estimated river miles of our trapping and release locations are as follows:

Knights Ferry release site	RM 54.3
Orange Blossom Bridge	RM 46.9
Highway 120/108 release site	RM 41.2
Pipe release site	RM 40.6
Oakdale trapping location	RM 40.1
Caswell trapping location	RM 8.6

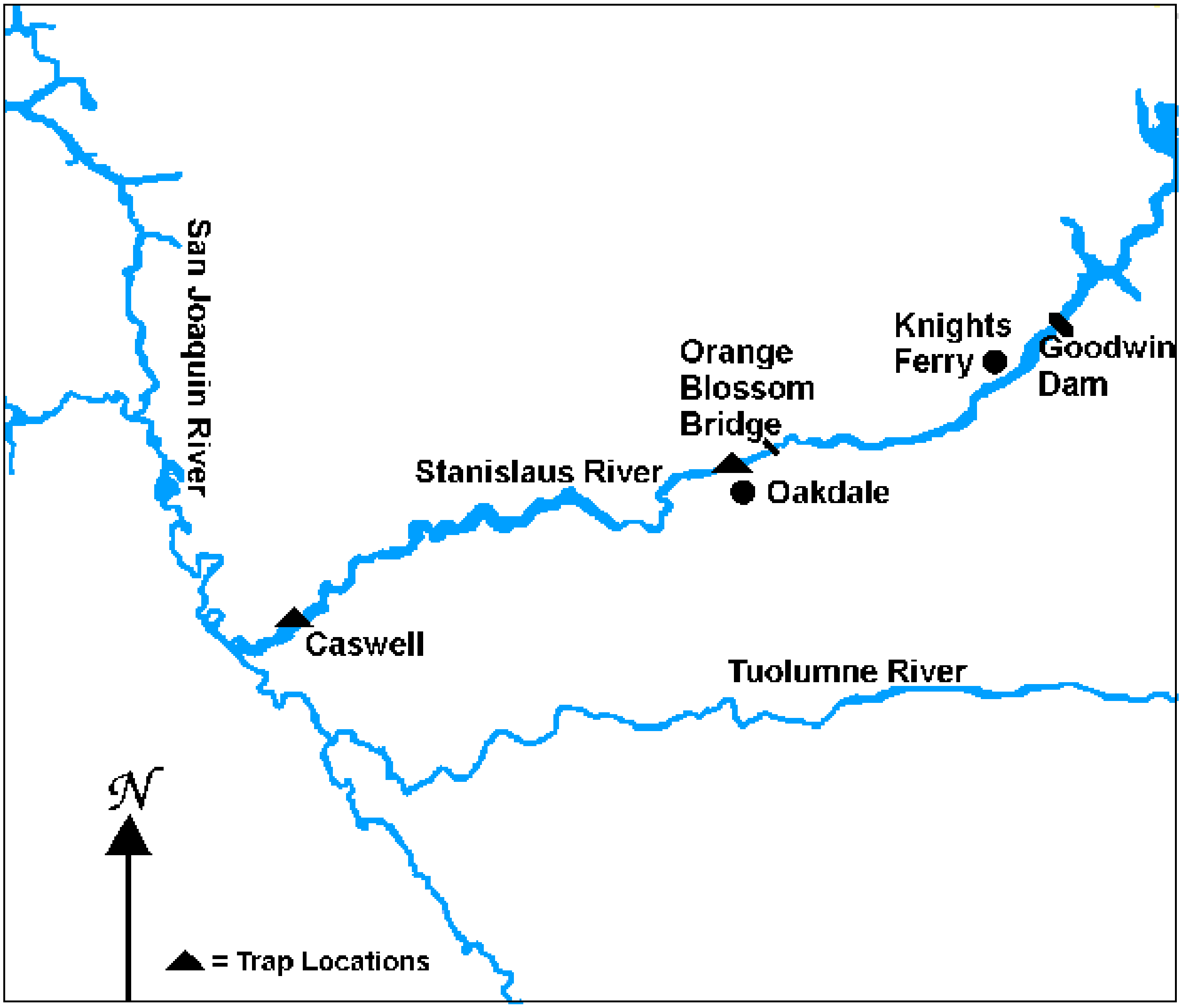

Figure 1. **Location map of San Joaquin Basin and Stanislaus River.**

SUMMARY OF RESULTS

As requested by the San Joaquin and Oakdale irrigation districts, S.P. Cramer and Associates began fishing a rotary screw trap in the river near Oakdale (RM 40.1) in the spring of 1993 to index the timing and abundance of outmigrating juvenile chinook during different flows. Since then, sampling has been conducted at the site in most years (Table 1). Sampling efforts have begun earlier each year since 1996 with the goal of estimating the total number of juvenile chinook outmigrants.

Since 1995, S.P. Cramer and Associates has also marked, released and captured natural migrants and hatchery chinook to evaluate trap efficiency. The fish are released at Knights Ferry and recaptured near Oakdale, 14.2 miles downstream. Information from the tests is used to expand rotary screw trap recovery rates as needed to estimate the number of chinook salmon migrating from the Stanislaus River.

Besides the Oakdale trap, S.P. Cramer and Associates also operates two traps near Caswell State Park under contract to the U.S. Fish and Wildlife Service. Although the projects are under separate contracts with separate research objectives, data collected at the lower river Caswell site complements work conducted under this contract. Relevant information from the study is presented and discussed in this report.

Summary of Findings

1993 The trap at the Oakdale site operated from April 21 to June 29. Trap catches suggested that juvenile chinook outmigration peaked for only 1-4 days, when flows in the Stanislaus River increased from 400 cfs to 1,400 cfs about one week after the trap was installed. The stimulant effect of flow on chinook migration, however, lasted only a few days and affected only a small portion of the population. Data did not indicate that sustained high flows "flushed" juvenile chinook out of the river.

1994 The trap at Oakdale was not operated. A trap operated by the California Department of Fish and Game at Caswell State Park ran April 23 to May 26 and sampled fish near the mouth of the Stanislaus River. Daily catches ranged from zero to 75 juvenile chinook and were highest following the first pulse in flow (late April). As in 1993, daily catches declined sharply within a few days after flows dropped. The catch rose shortly again in late May after another increase in flow.

1995 Investigations resumed at the Oakdale site, with the trap operating from March 18 to July 1. Sampling continued at Caswell. As in 1993 and 1994, results from sampling at Oakdale suggested that pulse flows stimulated juvenile chinook migration, but the effect lasted only a few days. Again, pulse flows did not seem to flush juvenile chinook out of the river.

1996 Sampling continued, with one trap at Oakdale and two at Caswell. SPCA began operating the traps in early February in an effort to sample the entire juvenile chinook outmigration, but fry had already begun migrating. Results showed that the estimated abundance of juvenile chinook at Oakdale and Caswell differed significantly—suggesting that juvenile chinook may encounter high mortality in the 31.5 miles between the two sites.

1997 Two rotary screw traps were fished at Caswell. No sampling occurred at Oakdale due to high flows. High flows also delayed sampling at Caswell until mid-March.

1998 Trapping at the two sites continued. The trap was installed on January 23, but high flows delayed sampling until January 26. Sampling continued through July 15, with fry outmigration peaking in mid-February and smolt outmigration peaking in early May. An estimated 598,873 chinook (417,185 fry, 60,041 parr, and 121,647 smolts) passed the Oakdale trap area during the sampling period.

1999 Sampling occurred at the two sites from January 18 through June 30. Results indicated that more than a million juvenile chinook passed the Oakdale site, with a notable difference in the daily mean length of fish captured between Oakdale and Caswell after mid-March. The capture of larger fish at Caswell than at Oakdale indicated rearing was taking place between the two sites.

2000 The sampling period was extended, beginning on December 16, 1999. Daily catches in mid-December were small, suggesting that sampling began near the onset of the chinook outmigration period. Fry outmigration rose significantly with large flow increases in January and February and, as in past years, dropped within a few days. Overall, study results indicate that more than 1.5 million juvenile chinook outmigrated past the Oakdale site. As in 1999, there was a noticeable difference between the daily mean lengths of fish captured at Oakdale and Caswell after mid-March, suggesting the rearing takes place between the two sites.

METHODS

JUVENILE OUTMIGRANT MONITORING

Trapping Site

To capture juvenile chinook migrants, we fished a rotary screw trap in the mainstem of the Stanislaus River near the Oakdale Recreation Area, about three miles west of the town of Oakdale, California. This trap site (RM 40.1) offered the farthest downstream location with adequate water velocities for efficient trap operation at low river flows. Fast water velocities are needed to maintain a high trap rotation speed and capture efficiency. The site lies downstream from most chinook spawning and juvenile rearing activity and was also fished in 1993, 1995, 1996, 1998 and 1999.

The trap, a funnel-shaped cone suspended between two pontoons, was manufactured by E.G. Solutions in Eugene, Oregon (Figure 2). It was positioned in the current with the 8-foot wide funnel mouth facing upstream. Water entering the funnel would strike the internal screw core, causing the funnel to rotate. As the funnel rotated, fish were trapped in pockets of water and forced rearward into a livebox where they could not escape. The trap was held in a static position in the main current by a 3/8 inch cable, which was suspended across the river about 40 feet above the water surface. Cables fastened to the front of each pontoon were attached to the overhead cable. This design held the trap in position while still providing adequate space for recreational river users to pass the trap safely.

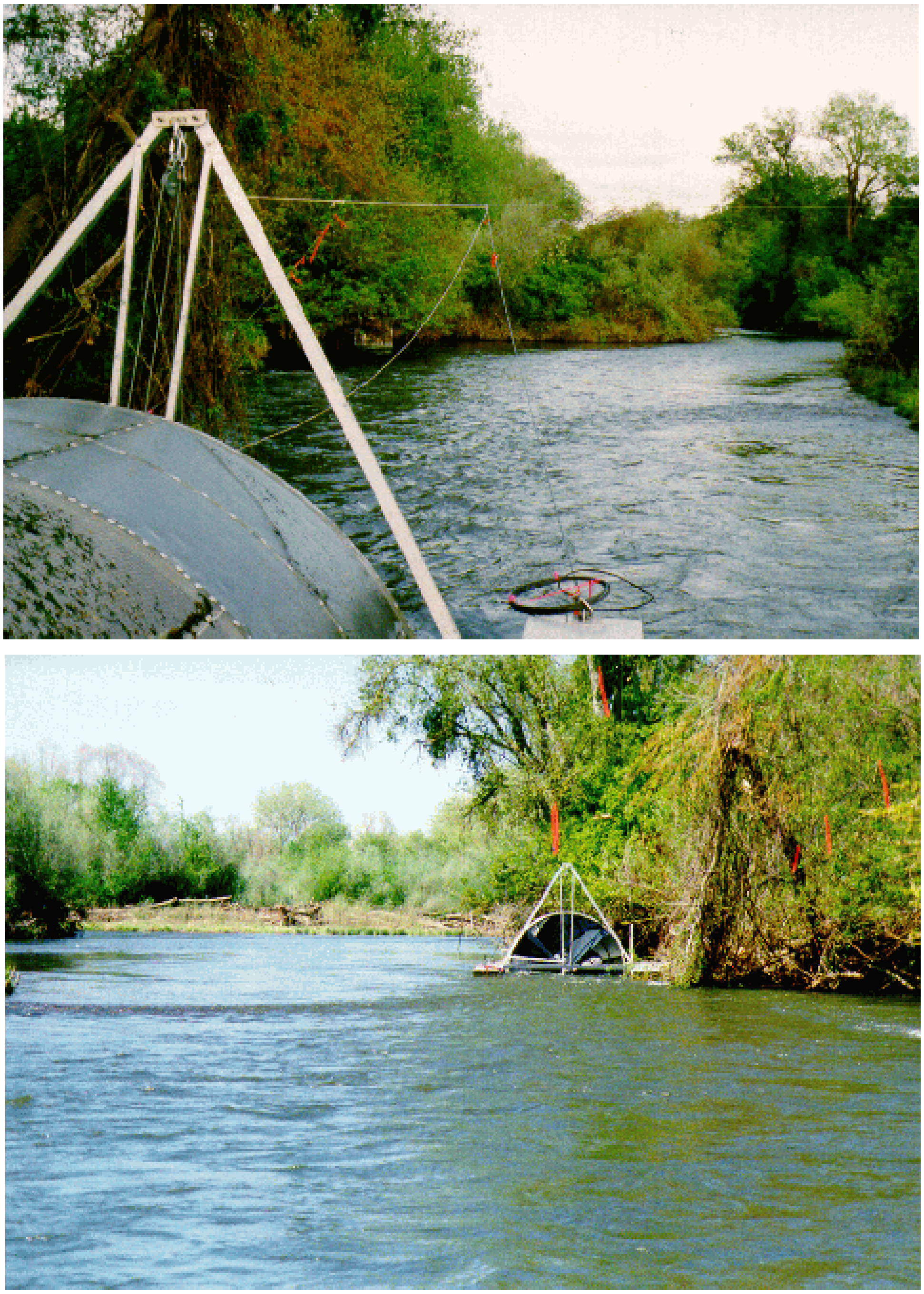

Figure 2. Photographs of the rotary screw trap.

Trap Monitoring

We installed the Oakdale rotary screw trap on December 13 and began sampling on December 15. Monitoring continued until June 30. We did not fish the trap during the Christmas holiday (December 24-27), New Year's holiday (January 1-2), or Memorial Day weekend (May 27-29). We also suspended our monitoring efforts on weekends in June because of safety concerns for the many recreational river users, particularly rafters, that float through the Oakdale vicinity beginning in late spring. On those weekends, we raised the trap's rotating cone from the water and pulled the trap closer to the banks, creating a wider passageway on the river.

Between December 15 and June 30, we fished the trap 24 hours per day, 7 days per week—except during times when the cone was raised because of high flows, trap malfunction, major holidays or safety concerns. We checked and cleaned the trap daily to prevent buildup on or in the cone where it could impair trap rotation. We also removed debris that accumulated against the trap and in the livebox. The debris load in the livebox was estimated and recorded whenever the trap was checked. During high winds, heavy rains or significant changes in flow—which usually increased the debris load—we checked the trap in the morning and at dusk, thus ensuring that the captured fish were not at risk due to a debris overload, and that the cone was operating properly. We also checked the trap several times daily during times of high turbid flows and when we had recently released marked fish to document daytime catchers of juvenile chinook. Following efficiency releases, we monitored the trap frequently until we were no longer recapturing marked fish.

Figure xx. Flows during outmigration sampling period in the Stanislaus River, 2000.

During natural freshets, we monitored the trap every two to three hours to reduce mortality of juvenile chinook fish, which rapidly accumulated in the livebox. We created areas for fish refuge in the livebox by placing a metal grate propped up by cinder blocks near the rear of the livebox. This grate helped separate the larger, more dangerous debris from other areas of the box, while the holes in the cinder blocks added stability and additional cover. This partial barrier also helped to reduce the current in the rear of the livebox, thereby reducing stress on the fish it contained.

Each day, we removed the contents of the liveboxes in the morning and identified and counted all fish captured. Then, we randomly sampled 50 chinook and 20 of each other species and recorded their lengths in millimeters. All rainbow/steelhead and yearling chinook were measured. We cleaned the traps after all fish were recorded. We also collected daily scale samples from a few chinook, which were randomly selected from the livebox each week after they reached the appropriate size and stage of development. In addition, we took scale samples from most of the captured yearling chinook by using a small knife to scrape away a few scales in the area just behind the dorsal fin and above the lateral line. Each sample was placed in a separate labeled envelope with the length of the fish, date, time and smolt index recorded on the outside.

Smolt Index Rating

Each measured chinook and all captured rainbow trout/steelhead were checked for visible signs of smolting. Chinook smolting appearance was rated on a scale of 1 to 3, with 1 an obvious parr (highly visible parr marks) and 3 an obvious smolt (silvery appearance, easily shed scales, blackened fin tips). We rated rainbow trout/steelhead on a scale provided by the Interagency Ecological Program (IEP) Steelhead Project Work Team. This steelhead smolting scale rates the fish on a range of 1 through 5, with 1 being a yolk-sac fry, 2 a fry, 3 a parr, 4 a silvery parr, and 5 a smolt.

EXPERIMENTAL RELEASE GROUPS

Trap Efficiency Releases

We released twelve groups of fish from January 11 through May 20 to determine trap efficiencies. Three of the release groups were hatchery-reared fish obtained from the Merced River Hatchery. The remaining nine groups contained natural juvenile chinook that we captured in the screw trap. Generally, we accumulated the fish over several days to have enough for a group. The first two groups of natural fish were marked by cold brand and the final seven natural groups were marked by dye inoculation using a photonic marking system. Between 118 and 1,856 fish were released in each group. All marked fish were released at dark.

Holding Facility and Transport Method

Fish were held in free-standing net pens measuring 4 ft x 4 ft x 4 ft and 2 ft x 3 ft x 3 ft. The net pens consisted of 3/16 inch Delta mesh sewn on frames constructed of ½ inch diameter PVC pipe. The net pens were placed inside a submerged chain-link style dog kennel, which was constructed in the river to protect fish from predators and human disturbances. The kennel was located near the trap in an area of low velocity.

Fish were transferred from the traps to 20-gallon insulated coolers for transport to the efficiency release site. Between 75 and 150 fish were placed in each cooler and transported a half-mile upstream from the trap for trap efficiency tests. The fish remained in the cooler for 15 to 45 minutes, depending on the circumstances. We always carried an aerator, but never needed to deliver oxygen to the coolers during transport.

Marking Procedure

Two methods, cold-brand and photonic marking, were used to mark juvenile chinook. All fish were anesthetized with MS-222 (Schoettger and Steucke 1970) before the appropriate mark was applied. Fish in two of the release groups were cold-branded by freezing a branding stick in a thermos of liquid nitrogen. The fish were then laid on a flat surface and the appropriate mark was applied by placing the tip of the branding tool against the front/rear, right/left section of the body of the fish. Minimal pressure was applied for approximately two seconds and each fish received only one mark. All marked fish were held for two or three days until the mark became visible.

A photonic marking system was used for marking most of the release groups because of the high quality of marks and the ability to use the marking equipment in rapid succession. With this method, a marker tip was placed against the caudal (top or bottom lobe), dorsal or anal fin and dye was injected into the fin rays. While one mark was applied to each fish, and all fish in a group received the same mark, the mark location was varied between groups so each group could be uniquely identified. Several different photonic dye colors were used to differentiate the groups including photonic pink, photonic blue, photonic orange, photonic violet and, photonic green. The dyes, purchased from NewWest Technologies of Santa Rosa, California, were chosen because of their known ability to provide a highly visible, long-lasting mark.

Pre-release Sampling

Marked fish were sampled for mean length and mark retention. Fifty fish were randomly selected from each distinctly-marked group and anesthetized. Mark retention was rated as present or absent. If a mark was absent on any of the 50 fish, an additional 50 fish were sampled. The proportion of fish found to have visible marks in each group was used to estimate the actual number of marked fish released by the expression:

*number released = proportion mark retention * number in group*

Release Procedure

To estimate trapping efficiency, the fish were released a half-mile above the trap, where the main Oakdale waste pipe crosses over the Stanislaus River. Before release, the fish were placed in a cooler filled with water and transported to the release site. We released the fish by placing a dip net into the cooler, scooping up about 10 fish and dipping the net into the river so they could swim away. After releasing a "net-full" of fish, we waited 30 seconds to 3 minutes before releasing another net-full of about 10 fish. The amount of time between releases varied depending on how fast the fish swam away after being released. Release time for the groups ranged from 15 to 45 minutes. This release procedure was similar to the one used in 1998 and 1999, as the fish were released directly from coolers instead of being transferred to net pens for release as in 1995 and 1996. All trap efficiency groups were released under total darkness in 1995, 1996, 1998, 1999 and 2000.

The 2000 Capture Efficiency Model

We calculated the daily outmigration index by dividing the number of chinook captured at Oakdale each day by the predicted daily trap efficiency (proportion of released fish that were later recaptured):

$$\textit{Outmigration Index} = \frac{\textit{Count}}{\textit{Efficiency}}$$

To predict the efficiency for each passage day, the efficiency estimates were viewed as a response (dependent variable) to the predictor(s) (independent variables) measured each day the screw trap operated. Three predictor variables were explored: flow (f) in cubic feet per second (cfs) measured at Orange Blossom Bridge, fish fork length (s) in millimeters (mm), and turbidity (t) in nephelometric turbidity units (ntu). Efficiency (e), the proportion of released fish trapped per release, was related to the predictor variables using the logistic relation:

$$\textit{efficiency}\ (e) = \frac{1}{1 + \exp^{[-b(0) - b(f) \times f - b(s) \times s - b(t) \times t]}}$$

or, using the "logit" linear transform,

$$\textit{logit}\ (e) = \ln\left[\frac{e}{1 - e}\right] = b(0) + b(f) \times f + b(s) \times s + b(t) \times t + b(s) \times s$$

In the above equations "exp" is the exponential function, "ln" is the natural log, "b(0)" is a coefficient associated with the intercept[1], and b(f), b(s), and b(t) are partial logistic regression coefficients relating the logit transform of efficiency to the indicated predictor variables. We used the logistic model primarily because the predicted efficiency can never be less than zero and can never exceed one (100%). The logistic regression we used

[1] Intercept value = $1/\{1+\exp^{-b(0)}\}$ when f = s = t = 0.

assumes that the underlying distribution of the number of captured fish is binomial when the model is accurate.

The predictor variables evaluated in the 2000 analysis were similar to those used in previous years. However, we used the indicator variables for different life stages (fry, parr and smolt) as a measure of fish size. In 1996 and 1998, we estimated total outmigration for each juvenile chinook life stage, where; fry < 45 mm; parr 45 mm to 80 mm; smolt > 80mm. Cut off dates for each life stage began when the daily mean lengths exceeded the previous stage for five of seven days; though the daily lengths of sampled fish over contiguous days can bounce above and below the values we used to separate the different stages. To address this, since 1999 we have used an algorithm to establish dates separating fry from parr, and parr from smolts. When the number of continuous days that fish fall into the larger life stage permanently exceeds the previous number of continuous days when the fish fell into the smaller life stage, we use the date between the two runs of days to separate the smaller and larger size classes. The measures for 2000 were (how different from 1999?):

Flow: The average of release-day and recovery-day flows. We used this measure because our releases occurred on the evening of the release day and almost all fish were recovered by the following morning (recovery day). Therefore, the average of the two days' flows was considered to be a better indicator of the flow during the recovery period than was the release-day flow. Overall, the predictor variable is the average of the flows from the day of capture and from the day before recapture.

Fish size: Size of recovered fish was used as a measure since the predictor would be applied to captured fish, which would presumably be better represented by fish recovered in the trap than by released fish. Length was also assessed using indicator variables for each life stage. Fish were assigned to different life-stages as follows based on their mean recovery size:

fry: length <= 45 mm

parr: 45 mm < length <= 80 mm

smolt: length > 80 mm

Turbidity: Recovery-day turbidities were used in the analysis for all four years. Turbidity levels were checked and recorded in the morning when the recovered fish were counted,

Linear interpolation was used to estimate missing predictor variable values from the nearest straddling days' values. For example, if there was a flow of 1,000 cfs on day four and a flow of 1,200 cfs on day nine, and if there were no intervening flow measures, then the missing values for day five through eight would be computed using values for the known flows. This method is described in the appendix.

To evaluate the effectiveness of each predictor variable (Table 3), we conducted an analysis of variation. The analysis of variation was applied to the residual logistic-regression deviancies, which are analogous the residual sums of squares from least squares regression. This method is also described in the appendix.

Table 3. Predictor variables and efficiency response variable used to develop logistic efficiency predictor.

Outmigration Abundance

Outmigration abundance was cumulated over the dates given in Table xx (page xx), which provides outmigration-index estimates of fry, fingerling, smolt, and total juveniles within years. These estimates were generated using a predicted daily efficiency (e) to expand the daily count (c) and obtain an estimated daily estimated outmigration index (o). The outmigration index estimate for a given day (o_i) is given in Equation 2.

Equation 2.

$$o_i = \frac{c_i}{e_i} = \frac{c_i}{\dfrac{1}{1 + \exp[-b(0) - b(f)f_i - b(s)s_i - b(t')t'_i}}$$

$$= c_i * \{1 + \exp[-b(0) - b(f)f_i - b(s)s_i - b(t')t'_i]\}$$

The outmigration indices represent an index and not true estimates of outmigration. Index estimates given for 2000 differ from those presented in past reports. Because of data modifications, the confidence intervals presented are generally narrower than in previous reports. In 1998, the confidence interval estimate was based, in part, on the approximate variance of a ratio (the ratio estimate being given in the first line of Equation 2), which turned out to be conservative (larger than it should). The variance estimate was improved in 1999 using an unbiased estimate of the variance of a product (the product being given in the second line of Equation 2). In 2000, the method for estimating the variance used for the standard error was changed again. As a result, the estimated standard errors shown in this report for 1996, 1998 and 1999 outmigration indices are usually slightly less than those given in the 1999 report, though the outmigration estimates are the same. The methodology is detailed in the appendix.

MONITORING ENVIRONMENTAL FACTORS

Flow Measurements

Daily flow data on the Stanislaus River was obtained from the California Data Exchange Center. All river flows cited in this report were measured at Orange Blossom Bridge by the U.S. Geological Survey. The flow data represent daily averages. Depth-velocity profiles were taken in front of the trap.

We used two methods to measure the velocity of water entering the trap. First, while checking the trap we measured water velocity with a Global Flow Probe, manufactured by Global Water (Fair Oaks, CA). Second, we calculated an average daily trap rotation speed of the trap. We determined the average time per revolution for the trap by measuring the time needed, in seconds, for it to make three contiguous revolutions. This measurement was taken twice daily, before and after cleaning, to ensure accuracy.

River Temperature and Relative Turbidity

Daily water temperature at the trap site was measured with a mercury thermometer. We also used Onset StowAway recording thermometers to record water temperature once per hour throughout the sampling season. These thermometers were installed at six sites on the Stanislaus between Goodwin and Caswell, including the Oakdale and Caswell sites. Daily average temperature was derived by averaging the 24-hourly measurements.

Turbidity was measured each day using a LaMotte turbidity meter, Model 2008. A water sample was collected each morning and later tested at the field station. Turbidity was recorded in Nephelometric Turbidity Units (NTU's).

RELATED MONITORING AT THE CASWELL TRAPPING SITE

Besides our screw trap near Oakdale, two screw traps were fished near the mouth of the Stanislaus River, adjacent to Caswell State Park (RM 8.6), under contract to the USFWS. The traps were operated from December 16 to June 30 to index juvenile chinook abundance. All data was collected according to criteria established by the USFWS.

RESULTS

OBJECTIVE 1: ESTIMATE THE NUMBER OF CHINOOK SALMON MIGRATING OUT OF THE STANISLAUS RIVER IN 2000.

TRAP CATCHES OF CHINOOK

Daily catches of juvenile chinook between December 16 and June 30 ranged from 0 to 28,173 fish, and totaled 119,310 fish in 2000—roughly four times as many as were captured in 1998 or 1999 (Figures x). The trap was fished daily, excluding the Christmas and New Years holidays, and weekends from Memorial Day through June. Daily catches for December suggest that we began sampling near the onset of the chinook outmigration period, as our catches the first eight days were small, between 25 and 2 fish daily. The daily catch rose in late December and early January, with a high catch of 903 chinook on January 10—still eight days before we started sampling in 1999. This confirmed our belief that fry emerge throughout the winter and that trapping in 1996, 1998 and 1999 missed much of the fry passage from the winter emergence. Our degree day analysis indicates that fry emergence started [when].

Figure xx. Daily catches of juvenile chinook and Stanislaus River flow, 2000.

TRAP EFFICIENCY

Between January 11 and May 20, we released nine groups of marked natural chinook and three groups of marked hatchery chinook to estimate trapping efficiency (Table xx). We made the natural chinook releases after catching enough naturally migrating fry early in the season to justify using some of the fish in our trap efficiency tests. As requested by CDFG, we limited our releases of naturally produced fish to once per week. We made nine releases of naturally produced fish in 2000, compared to fifteen releases in 1999. All releases occurred at night in flows ranging from 333 cfs to 4,187 cfs. Capture rates of marked fish ranged from 0% to 21.91%. Our highest recapture rates (17.91%-21.91%) all occurred early in the season when fish were in the fry stage and flows were between 333 and 343 cfs. Recapture rates dropped when larger fish were released.

Table xx. Date, stock, location, time, number of fish released and river flow for trap efficiency, migration rate and survival tests in the Stanislaus River during 2000.

Release Code	Release Date	Mark Type	Stock	Adjusted # Released	Number Recaptured	Percent Recaptured	Mean at Release	Mean at Recapture	Flow
O1	11-Jan-00	Cold Brand	Natural	530	103	19.43%	34.6	35.61	335
O2	21-Jan-00	Cold Brand	Natural	118	21	17.80%	34.5	35.00	343
O3	02-Feb-00	Photonic	Natural	397	87	21.91%	36.0	34.88	339
O4	09-Feb-00	Photonic	Natural	402	80	19.90%	35.3	34.67	333
O5	18-Feb-00	Photonic	Natural	477	9	1.89%	35.5	35.22	1860
O6	26-Feb-00	Photonic	Natural	970	10	1.03%	36.0	37.00	2615
O7	05-Mar-00	Photonic	Natural	239	4	1.67%	35.0	36.25	4187
O8	18-Mar-00	Photonic	Natural	346	5	1.45%	49.7	46.60	1550
O9*	25-Mar-00	Photonic	Natural	441	0	0.00%	56.4	-	846
O10	18-May-00	Photonic	Hatchery	1694	21	1.24%	86.8	84.81	1528
O11	19-May-00	Photonic	Hatchery	1461	16	1.10%	83.2	84.88	1517
O12	20-May-00	Photonic	Hatchery	1856	11	0.59%	85.6	81.18	1504

Size Selectivity of Screw Trap

[**This subsection (as written) was in the 1999 report. Findings don't seem consistent with our analysis showing that trapping efficiency may be higher for smaller fish. I suggest we drop this subsection.]**

Our comparisons of fish size before release and at recapture showed that the mean length of recaptured chinook did not differ significantly from the mean length of fish at release (see Table XX and Figure XX). This suggests that trap efficiency does not change with fish size. The predictive method used to determine if the trap caught more of the small fish or large fish from the trap efficiency release groups assumed that the trapped fish would represent all fish passing the trap.

Figure 5. Mean lengths at release and recapture for all marked fish released in 2000.

Trap Capture Efficiency Comparison Between Years

Daily counts from the screw trap were available from February 2 to June 8, 1996, from January 27 to July 15, 1998, from January 18 to June 30, 1999 and from December 16, 1999 to June 30, 2000 (referred to as passage days). On 44 days during these monitoring periods for the four years combined, we made a total of 48 uniquely marked night releases. The fish were released at a fixed location upstream from the Oakdale screw trap to estimate trap efficiency. In all years, we made our trap efficiency releases from the same location and using the same release procedures.

No one variable, such as flow or fish size, seemed to improve trap capture efficiency repeatedly during tests conducted from 1996 through 2000. However, these years have all been high flow years for the Stanislaus River basin and certain variables may influence efficiency more in low flow years. For example, in 1996 and 2000—the only years when tests were conducted in flows below 1,000 cfs—the highest recaptures occurred during low flows. In 1996, more fish (24%-28%) were captured on the three study days when flows were below 950 cfs. There was no apparent relationship between fish size and trap efficiency during this study season. While fish captured on the day of the highest trap efficiency (Feb. 12) averaged 30 mm, they averaged 78 and 91 mm on the next highest recapture days (May 26 and 29). In 1998, all releases were made in flows over 1,500 cfs and the highest recapture rates occurred late in the season when released fish averaged over 97 mm and flows over 2,000 cfs. In 1999, all releases were made in flows above 1,100 cfs. Capture rates of marked fish ranged from 0.26% to 3.77% during the season and trap efficiency was slightly higher for fry than for parr and smolt, especially considering that flows were 3,500 cfs to 4,160 cfs during tests in February and early March. In 2000, flows during the efficiency tests varied from 333 to 4,187 cfs. The highest recapture rates (17.91%-21.91%) all occurred early in the season when fish were in the fry stage and flows were between 333 and 343 cfs.

Presently, we are limited in efforts to compare recapture rates from the efficiency tests between years. Besides having only a few years of data—gathered under different environmental conditions—we have changed our method of analysis several times to improve precision. In 1996 and 1998, the results of the efficiency tests did not vary substantially or significantly and we were able to combine our analysis for these years and better estimate the efficiency rates for times when tests were not conducted. In 1999, we used different measures as the predictor variables (flow, fish size and turbidity) and the data could not be compared easily with that from 1996 and 1998. Still, our analysis of the variable procedure used in 1999 showed that none of the variables significantly or substantially increased precision and the predictor used was simply the weighted mean of the efficiency estimates (the weights being the number of fish released). Since the precision of the 1999 predictor was poorer than for the 1996 and 1998 predictors, we again made changes in 2000; this time using indicator variables for different life stages (fry, parr and smolt) instead of fish size. This change resulted in greater precision (a smaller mean deviance). The model's precision again increased significantly when we included flow in addition to fish size or the life stage indicators. Turbidity did not substantially increase the model's precision. Thus, the 2000 logistic predictor included life stage indicators and flow.

ABUNDANCE OF CHINOOK OUTMIGRANTS

During 2000, an estimated 1,801,098 chinook (95% CI xx-xx) outmigrated from the upper Stanislaus River during the season from December 16 to June 30, 2000 (see Figure xx, Table xx). This includes an estimated high of 1,146,201 fry, 591,620 parr, and 63,276 smolts. Outmigrant abundance in 2000 was greatest on January 25 (Figure xx) when fish were still at the fry (< 45 mm) life stage. We estimate that 182,520 chinook fry migrated past the trap that day.

Estimated outmigration abundance for 1999 and 2000 suggest that more than 1.5 million juvenile chinook migrate down the Stanislaus River past Oakdale in most years. Our estimates of chinook outmigrant abundance at Oakdale were smaller in 1996 and 1998, however the studies began later in those years and missed part of the run. Outmigration was sampled during a larger share of the outmigration period during the 2000 study year. Approximately twice as many juveniles in the 30 mm to 35 mm range were captured at Oakdale than at Caswell in 2000. These lower trap capture results at Caswell suggest that many of these juveniles are lost to predation or rear between the two sites.

Figure xx. Daily abundance of outmigrant chinook and river flow.

Figure xx. Cumulative outmigration index at Oakdale for 1999.

The year 2000 fry outmigration estimate of 1,146,201 fish was respectively 750% and 46% greater than those in 1996 and 1998, but 4% less than in 1999. However, it is difficult to accurately compare fry outmigrations between years because monitoring began at different points during the migration season. Monitoring began on December 16 for the year 2000 study—considerably earlier than in previous study years, which began on February 2, 1996, January 27, 1998 and January 18, 1999. Also, in each evaluated year before year 2000 the fish count exceeded 300 fish on the initial date, while in the year 2000 the initial count was 25 fish. This indicates that trappings in 1996, 1998 and 1999 probably missed much of the fry passage from the winter emergence. Further, our outmigration estimates reflect several statistical assumptions—such that all fish trapped were outmigrating, that about the same number of fish migrate during the day as during the night, and that released fish are representative of the river-run population. Thus, comparisons of outmigration indices between years are only accurate to the degree that our assumptions are correct.

Parr abundance was fully sampled in 1996, 1998, 1999 and 2000. In 2000, we estimated the parr outmigration at 591,620 fish. This outmigration estimate was 61% less than that for 1999, but sharply exceeded those for 1996 and 1998 (1,664% more than that of 1996 and 842% more than that of 1998). However, the large differences in the parr outmigration for 1996, 1998 and 2000 many not actually have been that significant. There was a large standard error associated with the 1998 estimate and a low standard error for the 2000 estimate, which are partially attributed to the limited number of efficiency releases for parr. Only two of the 2000 releases contained parr. To make the outmigration index estimates more accurate, in the future we could increase the number of efficiency releases within each life stage. The differences between years are also directly related to the number of days during which sampled chinook fell into the parr size class. The period when outmigrant parr fit the criterion (> 45 mm and < 80 mm) lasted only 10 days in 1996, 45 days in 1998 and 64 days in 1999. In 1999, the mean length was very near 80 mm for an extended period. Thus, an 80 mm demarcation between parr and smolt might be somewhat artificial, especially for the 1999 outmigration.

The 2000 smolt outmigration was estimated at 65,538 fish—the smallest of all years since efficiency tests began. This is less than half the number of smolts estimated to have outmigrated in 1996 and 1998, and 38% less than in 1999.

Figure xx. Fish abundance by life stage classification 1996-1999.

Table xx. Cumulative outmigration at Oakdale during the fry, parr, and smolt life-stages in 1996, 1998, 1999 and 2000.

RATE OF JUVENILE CHINOOK MIGRATION

Average migration rates, estimated using the recaptured fish from the 2000 Oakdale efficiency releases, varied from xx to xx miles/night among the different release groups (maximum= xx miles/night, minimum=xx miles/night). [I can't find information to update this]

Table xx. Recaptures from Oakdale efficiency groups at Caswell State Park.

Generally, the released fish traveled faster with increased flow. In 2000, fry travel increased from about 5 miles/day in flows below 1,500 cfs, to over 6 miles/day in flows of from 2,500 to 3,500 cfs, to about 9 miles/day in flows over 3,500 cfs. Parr travel increased from about 6 miles/day in flows below 1,500 cfs to over 10 miles/day in higher flows. Smolt rate of travel increased from about 8 miles/day in flows below 1,500 cfs to more than 9 miles/day in flows above 1,500 cfs.

In a related study conducted by S.P. Cramer and Associates, coded wire tagged juvenile chinook were released at Knights Ferry and then captured at Oakdale and Caswell. The study was designed to examine smolt survival. On May 18, about 75,000 fish were released at Knights Ferry. The fish began arriving at the Oakdale trap (14.2 miles downstream) that night. By the following morning, 339 fish had been captured. The catch rate then dropped on subsequent days. Through May 25, a total of 539 (0.7%) of the fish were captured.

Tagged chinook smolts were also released at Oakdale and recovered at Caswell, almost 32 miles downstream. About 1,695 smolts were released on May 18. They began arriving at Caswell the night of May 19, with 46 captured by the following morning. Tagged fish were also released on May 19 (about 1,460 fish) and 20 (about 1,855 fish). Through May 25, a total of 125 fish (0.17%) were recovered. Of the 5,011 fish released at Oakdale for trap efficiency evaluations, only 9 fish (0.18%) were recaptured at Caswell (Table xx).

Outmigration past Oakdale and Caswell

[**needs to be completed]**

The number of chinook outmigrating past Oakdale and Caswell sites were compared to estimate fish survival between RM 40.1 and RM 8.6. Overall, in 2000 more fish passed the Oakdale (xx chinook) trap than the Caswell (xx chinook) trap. This suggests that xx% of the fish (xx chinook lost out of xx) were subject to mortality or extraction between the two sites. Only a small proportion of the difference occurred between the categories of fry and smolts (xx%- xx fry and x%-xx smolts), while xx% of the difference was in the parr category (xx parr) (Figure xx). Most parr that passed Oakdale may have grown to the smolt size category before reaching Caswell, but survival of such rearing fish most have been low, because both the number of parr and smolts estimated to pass Caswell were less than those passing Oakdale.

Figure 9. Abundance of fry, parr and smolts at Caswell and Oakdale, 1999.

OBJECTIVE 2: DETERMINE THE SIZE AND SMOLTING CHARACTERISTICS OF JUVENILE CHINOOK SALMON, RAINBOW TROUT AND STEELHEAD MIGRATING OUT OF THE STANISLAUS RIVER.

LENGTH AT OUTMIGRATION

The mean lengths of juvenile chinook captured at Oakdale gradually increased from about 35 mm at the start of sampling in mid-December, to about 47 mm in mid-March, 65 mm in early April, 81 mm in early May, and 97 mm in late June (Figure xx). The gradual increase in mean lengths seen during 2000 resembled the patterns seen in 1998 and 1999—though chinook were smaller in 1999. A different pattern was seen in 1996 as fish lengths changed little during the fry outmigration, increased quickly for parr, and slowed again during the smolt stage.

Figure xx. Mean lengths of chinook captured at Oakdale in 2000.

Mean Lengths of Natural Migrants Between Years

During our studies from 1996-2000, fry captured at Oakdale were similar in length—averaging about 35-37 mm from December through February—though fish captured in 1999 were slightly smaller. By late March each year, most fish caught at the site had reached the parr stage. However, the time each year when parr began to dominate the catch differed by a week or two, with most chinook in 1998 reaching the parr stage earliest. In 1998, parr began to outnumber fry in the catch by March 7. They dominated the catch by March 12 in 2000, March 17 in 1996, and March 23 in 1999. Variations in growth rates between years continued throughout the parr stage—with fish in 1996 growing much faster than fish in other years.

Overall, the gradual increase in mean lengths seen over time in 2000 resembled the pattern seen in 1998 and 1999. In 1996, a more sigmoidal pattern was observed, with fish lengths changing little during the fry outmigration, increasing quickly during the parr stage, and then slowly again during the smolt stage (much like the fry stage). (Figure xx). This rapid increase in length from fry to smolt has not been observed since. While trapping results for 1996 classified most chinook outmigrants as parr for 21 days, results from the following years showed the parr outmigration lasting much longer. Parr dominated the outmigration for 43 days in 1998, about 63 days in 1999, and 60 days in 2000.

The estimated smolt outmigration index of 63,276 fish for the year 2000 was the smallest of all sample years. It was 53% below the estimated indices for 1996 and 1998, and 38% less than that of 1999—even though smolts dominated the run longer in 2000 than 1999.

Variations in fish lengths seen each year, especially from March through April, suggest that other factors play roles in determining when juvenile chinook are stimulated to migrate. For instance, environmental factors—such as water temperature and turbidity—may influence the length at which juvenile chinook migrate. These factors are discussed below. Several other factors may also affect the length of migrants, but are not examined in this study. For example, late fall spawners may produce the smaller fish seen later in the season. Better information on spawners—while not yet incorporated into the study—could help us determine how biological and physical variables affect growth and length of chinook at outmigration. In addition, density dependence, with territorial behavior and habitat availability, may explain the difference in parr and smolt lengths in some years. Since chinook are highly territorial and their territory expands as they grow, many fish could be displaced downstream in search of unoccupied habitat during years when juvenile densities are high. Fish abundance—another important factor that could affect growth—also deserves more consideration. To explore this potential relationship, however, we need better information about fish abundance in the Stanislaus River.

Figure xx. Mean lengths of chinook captured at Oakdale, 1996-2000.

Influence of Temperature on Length at Outmigration

Study findings on the Stanislaus suggest that water temperatures influence growth of juvenile chinook rearing and outmigrating in the river. During the 2000 study period, juvenile chinook rearing in the Stanislaus River generally experienced slightly warmer water temperatures in winter and spring than did fish in previous years. River temperatures near Goodwin Dam during early winter 2000 ranged up to four degrees warmer than in 1999—the coolest study year of record. In January 2000, the river temperature averaged 50 degrees, compared with 48 degrees in 1999. From February through March, temperatures ranged from 51 to 54 degrees, compared with a range of 48 to 53 degrees in 1999. Juvenile fish rearing and outmigrating in the Stanislaus River during 2000 were also generally larger than in 1999.

We did not find a strong relationship between water temperature and growth when we compared information from the 2000 study year with that from 1996 and 1998. Water temperatures were higher in 2000 than in 1996 and 1998, but only by one or two degrees. There was no noticeable difference in the size of fry chinook captured for these years. However, in 1996 the fish were larger once they reached the parr stage—even though water temperatures remained similar. This suggests that temperature influences fish growth, but is not the only factor.

Figure xx. Average monthly temperatures at Goodwin Dam 1996 through 1999.

Study findings also suggest that incubation temperature during fall and early winter, which plays a key role in chinook development and emergence, may also partially explain differences in juvenile chinook lengths in the Stanislaus River. Similar to fish outmigrating in 1996(?) and 1998, fish outmigrating in 2000 experienced warmer incubation temperatures during November and December [true? I didn't have the temperature information needed to look at this.] than did those outmigrating in 1999, and were also larger in length. Thus, fish in 1996, 1998 and 2000 may have emerged from the gravel slightly earlier and had a head start on growth compared to fish that outmigrated in early 1999 when waters were cooler (Figure XX).

Figure xx. Fall spawning and incubation temperatures for 1996 (1997 fry), 1998 (1999 fry), and 1999 (2000 fry) at Goodwin Dam.

Influence of Turbidity on Length at Outmigration

At the beginning of the year 2000 study, flows in the Stanislaus River averaged about 335 cfs and turbidity near 1 NTU. Flows remained stable until January 25, when the average river flow climbed to 752 cfs. This increase in flow caused a corresponding increase in turbidity, which rose to 25.6 NTU's. These conditions likely spurred fry movement as the estimated number of outmigrants increased from about 1,260 fish/day in mid-January to about 182,520 fish on January 25. While flows dropped the following day, turbidity remained high (11.2 NTU's) and a large number of fry continued to migrate, with outmigration estimated at about 142,220 fish on January 26. Fry migration also rose in February following peak flows and associated increases in turbidity from 2.6 NTU's on February 10, to 63 NTU's on February 11 and 31.7 NTU's on February 13. Outmigration also rose slightly in May after increases in turbidity, even though flows remained stable.

Some studies suggest that during turbid conditions juvenile fish may engage in activities, such as increased feeding, that would otherwise be risky (Ginetz and Larkin 1976). If turbidity promotes greater foraging activity and extends the suitable habitat range by providing cover, then we would expect larger fish to be produced in years of high turbidity. Our review of turbidity levels in 1996, 1998, 1999 and 2000 revealed that, overall, turbidity levels were similar, but lowest in 1999 and highest in 1998. However, the 1996 and 1998 seasons started later and there may have been earlier periods of high turbidity in January and February. The observed differences in turbidity between years (Figure 15) do not correlate with differences in chinook lengths. For example, chinook parr grew rapidly in 1996, then grew more slowly during the smolt stage. This rapid increase in length from fry to smolt was not observed in 1998, 1999 or 2000, though the river displayed similar flow, turbidity and temperature conditions.

Increases in turbidity may cue fry outmigration as the smaller chinook may prefer to migrate during turbid conditions when low visibility reduces the risk of predation. It may also allow some fry—especially during January and February—to migrate downstream to areas with better forage, as study results suggest that some chinook outmigrants may rear between Oakdale and Caswell.

Figure xx. Turbidity levels for 1996, 1998, 1999 and 2000.

Comparison of Mean Lengths at Oakdale and Caswell in 2000

As in 1999, chinook parr and smolts captured in the Caswell traps in 2000 were noticeably larger than those caught at Oakdale. This difference was not seen in previous years. Studies from 1996 and 1998 show that fish from the two sites were similar in length.

At the beginning of the 2000 study, fish from the two sites were about the same length. However, by the first week of March, chinook parr dominated the catch at Caswell (averaging about 48 mm), while chinook fry (averaging about 39 mm) still made up most of the catch at Oakdale. The gap narrowed as the season progressed. In 1999, the difference in fish length between the sites was most dramatic in mid-April when fish averaged about 60 mm in length at Oakdale, but were already 75 mm at Caswell. This large difference was not seen in mid-April 2000. Chinook captured at Oakdale in mid-April 2000(averaging 66 mm) were larger than those caught at the site in 1999; and fish caught at Caswell were smaller (averaging about 70 mm). Still, results from 2000—while not as significant as seen in 1999—continue to suggest that fish rear between the two sites.

Figure xx. Comparison of mean lengths at Oakdale and Caswell in 1999.

Figure xx. Comparison of mean lengths at Oakdale and Caswell in 1996 and 1998.

SMOLT APPEARANCE

Chinook captured in the trap began showing more visible smolt characteristics in mid-March (Figure xx), when the daily mean smolt index gradually increased from 1 to 2. By mid-May, smolts made up most of the catch at the trap, though individual fish that were not distinctly smolts appeared through June and ranged up to 100 mm in length. Fish that were distinctly smolts (index = 3) were 80 mm and above, and began appearing in early June.

Figure xx. Mean daily smolt index value of natural chinook captured in the Caswell screw traps during 2000 and lengths of juvenile chinook.

Chinook smolts began to dominate the catch at Oakdale about two weeks earlier in

2000 than in 1999, but about three weeks later than in 1998 and seven weeks later than in 1996. Overall, however, smolt indexes for 1998, 1999 and 2000 show little variation. Fry (smolt index 1) were present through the end of April in 1998, 1999, and 2000 except for one fry captured in late May 1999. Parr (smolt index 2) appeared later in 1999 (beginning of March) than in 1998 and 2000 (late February), but in all years parr outmigrations persisted until mid-June. In all three years, smolts (smolt index 3) were observed from mid-April through the sampling period. As noted before, parr and smolts appeared much earlier in 1996 than in the other study years. The difference in the timing of parr could be attributed to a variety of factors affecting growth and development, which have been mentioned previously in regards to length.

RAINBOW TROUT/STEELHEAD

During the sampling season, we captured 45 rainbow trout/steelhead at Oakdale, ranging in size from 30 mm to 340 mm (Figure xx). The first rainbow/steelhead was captured on January 6 and the last on June 30. Rainbow/steelhead (> 200 mm long) were caught January through June, and young-of-year rainbow (<100mm) were caught March through June. As in 1999, two distinct size classes emerged from the data (200-300 mm and <100mm), most likely representing yearlings and young-of-year, respectively. The 2000 catch of 45 rainbow/steelhead was one more than caught in 1999 and much higher than in previous years, including the third highest count of 23 rainbow/steelhead in 1995.

Figure xx. Lengths of all rainbow trout/steelhead captured at Oakdale 2000.

OBJECTIVE 3: IDENTIFY FACTORS THAT INFLUENCE THE TIMING OF JUVENILE CHINOOK SALMON MIGRATING OUT OF THE STANISLAUS RIVER.

INFLUENCE OF FLOW ON CHINOOK OUTMIGRATION

River flow during the 2000 chinook outmigration remained stable near 350 cfs from the initiation of sampling in mid-December through mid-February, with the exception of one freshet exceeding 750 cfs in late January. Flow then gradually increased through February and early March, reaching about 4,000 cfs before dropping and leveling off around 850 cfs. Fluctuations between 850 cfs and 1,500 cfs occurred until mid-June followed by a gradual decrease to approximately 400 cfs by late June.

During the 2000 season, fry outmigration rose in January and February after significant increases in flows. As in 1996 and 1998, the passage peaks seen in January 2000 were associated with an increase in average flow from about 340 cfs to over 700 cfs. In January, outmigration grew from about 860 migrants on January 24 to 182,520 migrants on January 25 after average river flows rose from 447 cfs to 752 cfs. All together, about 324,735 juvenile chinook outmigrated during two days in this freshet—an event not sampled in pervious years. Fry passage peaked again in February, rising from about 9,970 migrants on February 11 to 114,040 migrants on February 14 when flow increased from an average of 359 cfs to 1,544 cfs. Fry outmigation then dropped after the peak flows declined and stabilized. Chinook migration did not rise significantly later in the study when flows increased to over 2,500 cfs, then to near 4,000 cfs, before dropping and stabilizing near 850 cfs. However, the later flow increases were largely associated with the parr and smolt outmigration. These results suggest that flow increases may have a larger impact on fry migration than on smolts (Figure xx).

The migration pattern observed in 2000 differed significantly from that in 1999, when there was little evidence of a relationship between flows and chinook migration in the Stanislaus River. Fry outmigration peaked in January 1999 as flows increased, but fry passage peaked again in early February as flows decreased and then again as flows increased. However, the 1999 study season began later than in 2000, when average flows were already above 1,000 cfs. During the 2000 study season, flows remained low and stable into mid-February, except for pulse flows in late January. Fry migration remained low during the periods of stable flow and peaked when flows rose quickly.

Migration down the Stanislaus River peaked in mid-February during 1996 and 1998 (fry outmigration was not sampled in 1997). These peaks were associated with increases in average flow of 300 to 700 cfs. However, since sampling began later during 1996 and 1998, we do not know whether outmigration during these years increased in responses to changes in flow that occurred before mid-February. We were also unable to sample during the highest flows in 1998, which occurred in early February.

Some, but not all, increases in parr and smolt migration were associated with pulse flows during the 2000 study season. As in 1996 and 1998, we found that chinook smolts were stimulated to migrate by a distinct change in flow, but the effect lasted only a few days and only a portion of the fish were affected. The protracted period over which parr grow into the smolt stage (>80mm), probably reduces the proportion of fish that are physiological ready to migrate on any given date that flow changes. Also, in May 2000, several high catches occurred when turbidity increased, but flows remained stable.

Our study results suggest that the magnitude of flow during the fry outmigration may play a role in determining the proportion of the total population that will migrate as fry. If flows during the onset of fry emergence are stable, more fry may establish feeding behavior and territories before they drift downstream with high flows. This may have been the case during the 2000 study season—when few fry migrated during stable flows and many fry migrated during pulse flows.

Streamflow has previously been correlated with peak fry migration. In the Sacramento-San Joaquin Delta, Kjelson et al. (1981) found that peak catches were often associated with flow increases caused by storm runoff. They speculated that flow pulses stimulated fry migration from upper river spawning grounds. Other studies in the San Joaquin Delta tend to support the theory that a higher percentage of juvenile chinook migrate as fry in high flow years. For example, USFWS (1998) found that the abundance of chinook fry captured by seining in the northern delta between 1985 and 1999 was positively correlated (r=0.91) with the mean flow of the Sacramento River during February.

Figure xx. Fry outmigration index and flow for 2000.

Figure xx. Parr and smolt outmigration index and flow for 2000.

INFLUENCE OF TURBIDITY ON CHINOOK OUTMIGRATION

Peaks in fry outmigration during the 2000 study year were associated with increases in turbidity. In January, the number of captured outmigrants rose from about 1,260 fry/day in mid-January to 182,520 outmigrants when turbidity increased from 2 NTU's to 25.6 NTU's on January 25. While flows dropped the following day, turbidity remained high at 11.2 NTU's and a large number of fry continued to migrate. Fry migration also peaked in February when flows increased from about 350 cfs to 1,544 cfs and turbidity rose from 2.6 NTU's on February 10, to 63 NTU on February 11 and 31.7 NTU's on February 13. Several other peaks in outmigration were associated with turbidity alone. On several instances during May 2000 outmigration increased when turbidity rose, although flows remained stable (Figure xx).

Figure xx. Oakdale daily passage and turbidity.

Fry may choose to migrate during times of high turbidity. While little research currently exists on the relationship between turbidity and fry outmigration timing, many studies have related turbid conditions to reduced fry predation. Predators, such as birds and fish, use vision to detect and attack prey. High turbidity can impair visual abilities, thus reducing the detection range of predators and allowing small fish to outmigrate undetected. Studies suggest that juvenile fish take up more dangerous activities during turbid conditions, such as feeding (Gregory and Northcote 1993, Gregory 1994), using open water areas (Miner and Stein 1996), migrating (Ginetz and Larkin 1976), and seeking less cover (Gradall and Swenson 1982, Gregory 1993). Thus, fry may prefer to migrate during turbid conditions, and changes in turbidity could act as a cue.

INFLUENCE OF FISH LENGTH ON CHINOOK OUTMIGRATION

Variations in peak fry emergence among the years are probably not related to fish size, as fry were of a consistent range (35-45 mm) in 1996, 1998, 1999 and 2000. Fry were 35-37 mm at the onset of sampling and at outmigration. This size is within the ranges found for other populations (Mains and Smith 1964, Lister et al. 1971, Healey et al.1977 cited from Healey 1991).

In 2000, over 97% of the juvenile chinook in the year's outmigration past Oakdale migrated as fry. Parr and smolt outmigrants made up about 2.3% and 0.5% of the total outmigration, respectively. This migration pattern differed significantly from those seen in previous years. In 1999, the fry migration was also large (72.8%), but many fish also migrated as parr (22.4%). Smolts made up 4.8% of the1999 season outmigration. Findings from 1996 and 1998 show a larger contrast in outmigration patterns. In these years, the fry made up about half of the total outmigrants (51.8% in 1996 and 54.3% in 1998), but a large percentage of chinook also migrated as smolts (40.1% in 1996 and 29.7% in 1988). Fewer fish in these years migrated as parr (8.1% in 1996 and 16% in 1998). Thus, during these years chinook had a greater propensity to migrate when they were over 80 mm than when they were 45-80mm (parr). This differed significantly from the 2000 parr and smolt outmigrations when there was no clear relationship between their lengths and migration timing (Figure xx).

Figure xx. Mean length and chinook passage estimate.

INFLUENCE OF TEMPERATURE ON CHINOOK OUTMIGRATION

Stream temperature at Oakdale gradually increased from about 49º F at the start of sampling to 57º F at the end of June (Figure 24). Fluctuations in outmigration did not appear to correspond with changes in temperature during this time. It is possible that temperature influences outmigration is some ways, but the effects of temperature alone are difficult to measure.

Figure xx. Oakdale daily estimated passage and average daily water temperature.

<u>Influence of Incubation Temperature on Fry Migration Timing</u>

Water temperatures can be used to predict the start of fry emergence. Temperatures at Goodwin Dam were recorded and used to do a simple degree day analysis to estimate when fry first emerged. A degree day is 1 EF above freezing for one day. The sum of degrees above freezing for a given period of days would show how many degree days were experienced for that period.

(more work here)

CONCLUSIONS

SECTION INCOMPLETE

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- We did not make any day time releases because there were not enough fish available to justify additional releases—though information gained from such releases could help us estimate outmigration more accurately. Past day time efficiency releases conducted at Caswell in 1998 resulted in very few recoveries. This implies that either passage is lower during the day or fish passing during the day were not being caught. Thus, using efficiencies from night time releases to determine both night and day passage may underestimate the outmigration.

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APPENDICES